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DENSITY NEAR THE FORWARD STAGNATION POINT OF A BLUNT BODY IN A SUPERSONIC FLOW OF RAREFIED GAS

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DENSITY NEAR THE FORWARD STAGNATION POINT OF A BLUNT BODY IN A SUPERSONIC FLOW OF RAREFIED GAS *

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by A. V. Ivanov

SUMMARY

The object of this work is to determine the density near the forward stagnation point of a blunt body in a supersonic flow of rarefied gas, the investigated models being a sphere and a flat disk of same diameter. The thickness of the boundary layer is compared with the measured thickness of the shock wave, and it is found that the latter increases more rapidly than the former. On the whole, the results of this work lead to a contradiction with the possibility of existence of the "viscous layer regime" advocated by Probstein.

* * *

The decrease in density of a supersonic flow past a blunt body leads to the thickening of the boundary layer and of the outgoing shock wave. At latters' merging with one another there forms ahead of the body a uniform region of nonisoentropic flow. This region's formation process and the mechanism of the flow within it have hardly been experimentally investigated to date. The determination of density near the forward stagnation point of the blunt body, conducted here, allows to ascertain certain characteristic peculiarities of such regime, and, is possibly useful at construction of a model of flow.

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* PLOTNOST' VBLIZI PEREDNEY KRITICHESKOY TOCHKI ZATUPLENNOGO TELA OBTEKAYEMOGO SVERKHZVUKOVYM POTOKOM RAZREZHENNOGO GAZA.

The operation was conducted in an aerodynamic tube of low density [1]. The air was used as the operational gas. The density fields were determined with the aid of the electron sonde method [2], based upon the phenomenon of electron scattering from a collimated beam on gas molecules present in the volume investigated. The basic components of the device and the method of conducting the experiment were analogous to those described in the Hurlbut work [3]. The angular aperture of the detector of electrons constituted $1.5 \cdot 10^{-3}$ rad. The dimension of the registered electron beam was by one order less than the thickness of the compressed region ahead of the streamlined body. The energy of the electron beam was 2.2 kev and it was so chosen, that the equality be assured between the mean length of the free path of beam's electrons in the investigated volume and the distance from the electron gun to detector.

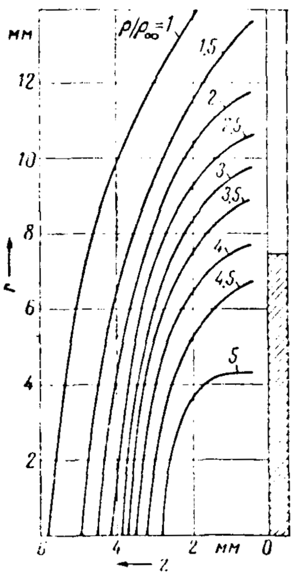

Fig. 1 The field of density ahead of the disk

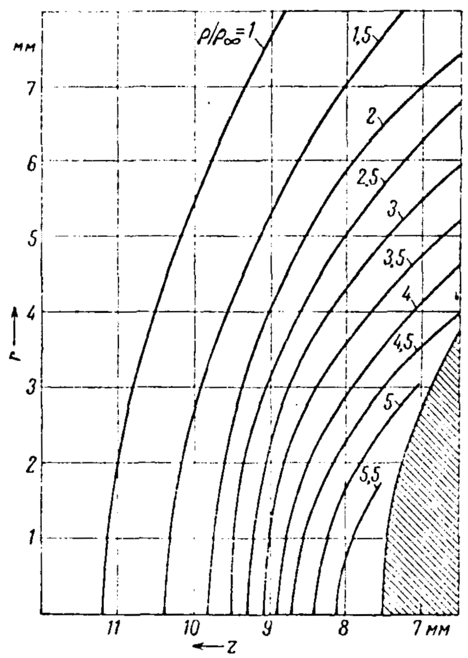

Fig. 2. - The field of density ahead of the sphere

Since the available gas flow was axi-symmetric, the local density was determined with the help of a method, similarly applied in shadow and intereferometer measurements of density. For models we utilized a sphere, radius of both bodies, was 220. The comparison of the density in the isoentropic core of the unperturbed incident flow, obtained by measurements with the help of the electron beam and computed by the number M, revealed an entirely satisfactory agreement.

The experimentally determined density fields ahead of the sphere and of the disk are plotted in Figs. 1 and 2. The distance from the axis r of the flow is plotted in ordinates and the axial coordinate z of the flow in abscissa, with the origin of the axis z being respectively placed on the surface of the disk and at the center of the sphere. The various curves refer to different values of density ratio $\rho(r, z)$ at the point r, z to ρ_∞ in the incident flow.

The variation of density ahead of the same disk and sphere along the deceleration line is shown in Fig. 3 and 4.

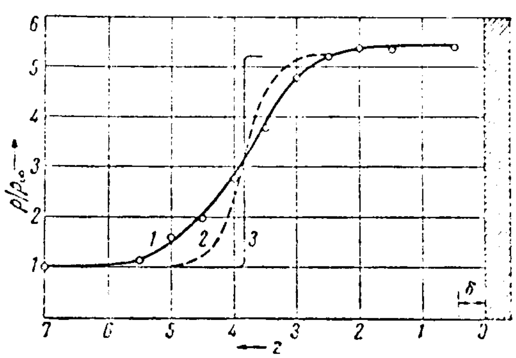

Fig. 3. - Density profile along the deceleration line for the disk. 1 — experiment; 2 - computation after Mott-Smith; 3 — jump in the continuum

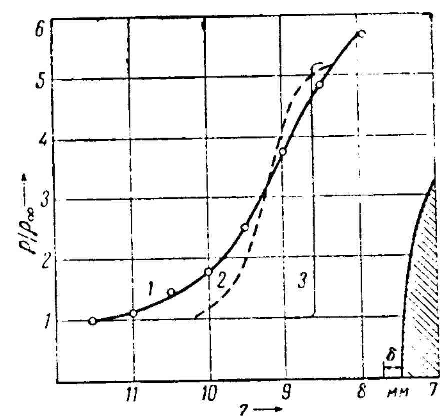

Fig. 4. - Density profile along the deceleration line for the sphere. 1 — experiment; 2 — computation after Mott-Smith; 3 — jump in the contiuum

The dashed curves represent the structure of the direct shock wave computed according to Mott-Smith theory [4] . The superpositior of these curves with the experimental was so effected that coincidence is obtained between the ordinate of Mott-Smith profile zero point with a certain point z of the experimental profile. The distance from the thus found point z to the forward stagnation point of the body resulted coinciding with the continual setting off the jump in the case of the disk, and differing from the latter for the sphere.

In case of a disk behind an outgoing shock wave, there exists a rather extended region, in which the density varies very insignificantly to the body itself and coincides within the experiment precision limits with its computed value behind a direct jump for a continual flow. This result shows, that the conditions of flow near the disk are nearly continual and it allows to calculate the thickness of the laminar boundary layer in the vicinity of the forward stagnation point with the help of methods worked out for the continuum [5]. For the case of heat-isolated surface, which corresponded approximately to conditions having taken place in the experiments, the computation value of the boundary layer thickness was found to be $\delta = 0.44$ mm. An analogous estimate, made for the case of flow past a sphere, gave $\delta = 0.22$ mm.

Comparison of the thus determined thickness of the boundary layer with the experimentally measured thickness of the shock wave shows, that the latter increases more rapidly than the former. At the same time, the thickness of the shock wave is significantly nearer the length of the free path of molecules in the incident flow λ_∞ (in our conditions $\lambda_\infty = 1$ mm), than the length of the free path of λ_s behind the jump ($\lambda_s = 2$ mm), as it was assumed in [6]. Therefore, the results of the current investigation lead to a contradiction with the possibility of existence of "viscous layer regime", introduced by Probstein.

The author expresses his gratitude to G. I. Petrov for his support and constant interest in the work, and to V. S. Avduyevskiy and V. A. Sukhnev for their counsel in the course of its realization.

*** THE END ***

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